Chapter 8
Muscle Physiology

Muscle cell is a machine that converts potential chemical energy into mechanical energy and heat energy.

Mechanical Energy = Work = force x distance

Heat Energy = waste energy
  - dissipate heat
  - store heat
  - leads to increased tissue temperature
  - can alter systemic homeostasis
Structure of Skeletal Muscle

- Muscle consists a number of muscle fibers lying parallel to one another and held together by connective tissue.
- Single skeletal muscle cell is known as a muscle fiber:
  - Multinucleated
  - Large, elongated, and cylindrically shaped
  - Fibers usually extend entire length of muscle

Structure of Skeletal Muscle

- **Myofibrils**
  - Contractile elements of muscle fiber
  - Regular arrangement of filaments
    - Thick filaments – myosin (protein)
    - Thin filaments – actin (protein)
  - Viewed microscopically myofibril displays alternating dark (the A bands) and light bands (the I bands) giving appearance of striations
(a) Relationship of a whole muscle and a muscle fiber

Muscle

Tendon

Muscle fiber (a single muscle cell)

Connective tissue

(b) Relationship of a muscle fiber and a myofibril

Muscle fiber

Dark A band

Light I band

Myofibril
(c) Cytoskeletal components of a myofibril
(d) Protein components of thick and thin filaments

**Thick filament**
- Myosin head
- Myosin tail
- Troponin
- Tropomyosin

**Thin filament**
- Actin

Fig. 8-2d, p. 197
Structure of Skeletal Muscle

• Sarcomere
  – Functional unit of skeletal muscle
  – Found between 2 Z lines
  – Regions of sarcomere
    • A band: Made up of thick filaments along with portions of thin filaments that overlap on both ends of thick filaments
    • H zone: Lighter area within middle of A band where thin filaments do not reach
    • M line: Extends vertically down middle of A band within center of H zone
    • I band: Consists of remaining portion of thin filaments that do not project into A band

Structure of Skeletal Muscle

• Titin
  – Giant, highly elastic protein (largest in body)
  – Extends in both directions from M line along length of thick filament to Z lines at opposite ends of sarcomere
  – 2 important roles:
    • Helps stabilize position of thick filaments in relation to thin filaments
    • Greatly augments muscle’s elasticity by acting like a spring
Myosin

• Major component of thick myofilament
• Protein molecule consisting of two identical subunits shaped somewhat like a golf club
  – Tail ends are intertwined around each other
  – Globular heads project out at one end
Myosin

• Tails oriented toward center of filament and globular heads protrude outward at regular intervals
  – Heads form cross bridges between thick and thin filaments
  • Cross bridge has 2 important sites critical to contractile process
    – An actin-binding site
    – A myosin ATPase (ATP-splitting) site
Actin

- Primary structural component of thin filaments
- Spherical in shape
- Thin filament also has 2 other proteins
  - Tropomyosin
  - Troponin
- Each actin molecule has special binding site for attachment with myosin cross bridge
  - Binding results in contraction of muscle fiber
Actin and Myosin

• Actin and myosin are often called contractile proteins because they are involved in bringing about sarcomere shortening
  – Neither actually contracts
  – Actin and myosin are not unique to muscle cells, but are more abundant and more highly organized in muscle cells

Tropomyosin and Troponin

• Often called regulatory proteins because they regulate the interaction between actin and myosin

• Tropomyosin
  – Thread-like molecules that lie end to end alongside groove of actin spiral
  – In this position, covers actin sites blocking interaction that leads to muscle contraction

• Troponin
  – Made of 3 polypeptide units that form important binding sites
    • One binds to tropomyosin
    • One binds to actin
    • One can bind with Ca²⁺
Tropomyosin and Troponin

- Troponin
  - When not bound to Ca\(^{2+}\)
    - Troponin stabilizes tropomyosin in blocking position over actin’s cross-bridge binding sites
  - When Ca\(^{2+}\) binds to troponin
    - Tropomyosin moves away from blocking position
    - With tropomyosin out of way, actin and myosin bind, interact at cross-bridges
    - Sarcomere transforms potential chemical energy into mechanical energy and heat

![Diagram of Tropomyosin and Troponin](image-url)
(b) Activated or excited (as a result of action potential)

Fig. 8-6b, p. 200

Fig. 8-7, p. 200

(b) Activated or excited (as a result of action potential)

Fig. 8-6b, p. 200

Fig. 8-7, p. 200